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Concept selection for engine components using the DEMATEL-ANP-TOPSIS combination method: a case study for cam bearing frame part

Y. Rabbani [1*], B. Asadi Moghaddam[2], E. Mardan[3], A. HajiAliMohammadi[4]

[1] *Faculty of Industrial Engineering, Engineering Department, Semnan University, Semnan, Iran,* Rabbani@semnan.ac.ir
[2] *Industrial Engineering research group, Engineering Department, Semnan University, Semnan, Iran,* b.asadi1373@gmail.com
[3] *Faculty of Industrial Engineering, Engineering Department, Semnan University, Semnan, Iran,* ehsan_mardan@semnan.ac.ir
[4] *Faculty of Mechanical Engineering, Semnan University, Semnan, Iran,* ahajiali@semnan.ac.ir
**Corresponding Author*

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ABSTRACT

Choosing the appropriate concept for the engine components and systems is one of the essential issues that influence directly on the cost and functional characteristics of the product. For selecting the right concept for an engine component, it is necessary to take different contradictory factors into account. Parameters like functional aspects, durability, cost of production, and assembly issues are common of interest for selecting the best concepts. In this research, concept evaluation and choosing the best concept for an engine component was investigated using multi-criteria decision-making techniques. The purpose of this study is to investigate the problem of selecting the appropriate cam bearing frame concept from the available four concepts based on 10 measurement indicators. For this purpose, this research is intended to use the DEMATLE-ANP-TOPSIS compilation method for modeling and solving the problem. In the beginning, using the DEMATEL method, the relationship between multi-criteria is determined, and afterward, the ANP method determined the weight of the criteria. Finally, the TOPSIS method was used to rank the options. The results, for the selected case, indicated that the two-piece ladder frame (concept 4) is the preferred option.

1) Introduction

Demand for high quality and low-cost components is increasing in the last decades for internal combustion engine components. For each engine component, various design concepts including material and geometric characteristics exist and the challenge of the component designer is to select the appropriate concept from various possible concepts [1-2].

There are many ways to choose the right concept for engine parts [3]. One of these methods is multi-criteria decision-making [4-5]. Today, multi-criteria decision-making methods are widely used in many different fields [6].

The reason for this is the ability and capability of these methods in modeling real issues and their simplicity and comprehensiveness for most users, companies, and manufacturers that evaluate their products according to their criteria and weights. This requires accurate, and cost-effective information on the assessment [7- 10].

The multi-criteria decision-making technique is the appropriate tool for decision-making in cases that involves series of evaluation parameters. Below, some relevant literature has been reviewed.

Tsai and Chou used the DEMATLE-ANP (Network Analysis Process) compilation approach to determine the weight of the criteria and used the VIKOR approach to rank options in the green field supplier selection for electronic components companies [11].

Llieva, used the fuzzy DEMATEL-ANP fusion approach to analyze the effective factors of official corruption [12]. In this research, corruption factors were classified and identified in four areas that include cultural, social, political, economic, and legal fields.

This method uses the fuzzy DEMATLE technique to identify the relationships between factors and the ANP technique to determine their significance.

Dehdasht et al. used the hybrid DEMATLE-ANP method to assess the risks associated with oil and gas development projects (OCGs) [13]. In this research, the DEMATLE method was used to identify the relative dependence between risks. The ANP method was also used to evaluate the relative importance of risk factors and choose the most appropriate strategy for implementing the venture management program.

In the area of building projects, Nilashi et al. have used the DEMATEL-ANP compilation technique to identify and prioritize key success factors (CSFs) [14]. CSFs are the vital aspects of building projects and generally are tools for improving project performance. In this research, five main criteria and 43 sub-criteria were considered. Initially, the DEMATEL technique was used to identify relationships and dependencies between criteria and sub-criteria, and the ANP technique after that was used to evaluate and prioritize the weight of key factors.

Shih et al. used the DEMATEL-ANP compilation method to select the most appropriate model for implementing information systems in an organization [15].

In this study, four important organizational dimensions with the perspective of a balanced scorecard include financial dimension (FI), customers and stakeholders (CS), internal business processes (IBP), and teaching and learning (LG) and their interdependencies extracted using the DEMATEL technique [16]. After that, Using the ANP method, the weight of the criteria and finally, the ranking of the three suggested options, including 1-in-sourcing-2-outsourcing-and 3-collaborative was obtained.

Aghaei and Fazli determined the factors influencing the selection of the appropriate net strategy, used the ANP, which there is a systematic interaction between the criteria for choosing the appropriate strategy and they used the methodology of the DEMATEL to determine the relationship between the criteria in Iran Khodro Diesel and Saipa Diesel companies [17]. The results of this research showed that the appropriate approach that is resulted from this hybrid method, for two companies, is preventive maintenance (PM).

Despite the wide application of multi-criteria decision-making techniques in different fields, there has been quite a few researches for selecting the appropriate design concepts for the IC engines, such as the paper of Egorov et al. [18], which is based on a multi-criteria approach and considered various, sometimes counterparty, indicators.

In this regard, the purpose of this study is to develop multi-criteria decision-making techniques based on a combination of DEMATLE-ANP-TOPSIS methods, for modeling and solving the problem of selecting the appropriate design concepts for the IC engines. Moreover, this technique will be applied for selecting the appropriate design concept for a sample engine component from four bearing frame concepts based on 10 measurement indicators.

2) Method of research

The proposed approach of this study is to use a method that consists of DEMATEL, ANP, and TOPSIS. In this method, at first, DEMATEL and ANP combination method is used to determine the weight and importance of the evaluation criteria, and then the resulted weights are used as inputs for the TOPSIS method to rank the options.

2.1) Computational steps of the DEMATEL-ANP-TOPSIS compilation approach

In this section, we demonstrate the steps of our proposed approach. Table 1 briefly shows the steps. In this approach, at first, a questionnaire will be completed by geniuses and experts in the related fields to clarify the aim of relationships and dependencies between the criteria. Then DEMATEL technique is used to identify the relations and dependencies. After the determination of the relationship, the ANP method is utilized. In this stage, by forming up the limited weighted supermatrix, the weight of the evaluation criteria is determined. Finally, TOPSIS is used to classify the evaluation options. Details of the process steps are presented below.

Step 1: Create a Direct Relation Matrix (M).

To compare the importance and dependency of the criteria by a comparison scale, a ranking scale from 0 to 4 is defined. The rankings are: 0 (no effect), 1 (low impact), 2 (average impact), 3 (high impact) and 4 (severe impact).

Step 2: Normalize Direct Relation Matrix (N).

To normalize the matrix, first of all, we need to calculate the sum of all rows and columns. Then we need to calculate K which is the Inverse of the largest number of rows and columns (Formula 1).

$$k = \frac{1}{\max\left(\sum_{j=1}^{n} a_{ij} v_i \,, \sum_{j=1}^{n} a_{ij} v_j\right)} \qquad (1)$$

After calculating the K value, the normalized matrix will be obtained by multiplying the K value by all elements of the direct relation matrix (M).

Step 3: Calculate the Complete Relation Matrix (T).

The complete relation matrix is calculated according to the following formula (formula 2).

$$T = N(1 + N)^{-1} \qquad (2)$$

Step 4: Create a causal diagram.

Table 1. The steps of DEMATEL, ANP & TOPSIS

DEMATEL-ANP	
Step 0- Define dimensions, sub-dimensions, and alternatives to build a framework	Step 3- Construct network structure of ANP
Step 1- Establish interdependences between dimensions	Step 3.1- Construct pair-wise comparison matrixes using ANP
Step 2- Construct initial direct relation matrix within dimensions using DEMATEL	Step 3.2- Calculate relative important weights of matrixes
Step 2.1- Normalize direct relation matrix	Step 3.3-Check consistency of Matrixes
Step 2.2- Construct total relation matrix	Step 3.4-Form a super-matrix by entering evaluations of DMs
Step 2.3- Compute dispatcher and receiver	Step 3.5- Normalize unweighted super-matrix and raise it to the power 2n+1
Step 2.4 Obtain inner dependence matrix	Step 3.6- Obtain RER selection criteria weights
Step 2.5- observe the causal relationship	Step 4-Find the most appropriate RER alternative
TOPSIS	
Step 1: Establish the decision matrix	
Step 2: Calculate a normalized decision matrix	
Step 3: Determine the weighted decision matrix	
Step 4: Identify the Positive and Negative Ideal Solution	
Step 5: Calculate the separation distance of each competitive alternative from the ideal and non-ideal solution	
Step 6: Measure the relative closeness of each location to the ideal solution	
Step 7: Rank the preference order	

The sum of the elements of each row (D) for each factor indicates its effect on other factors of the system (the effect of the variables). The sum of every element in each column (R), for each factor, indicates the level of its influence from other system factors (The severity level of influence of an element).

Therefore, the horizontal vector (D + R) is the amount of influence and effect of the factor in the system. So, the larger the D + R factor is, the more the interaction will happen with other system factors.

The vertical vector (D-R) shows the influence strength of each factor. Overall, if D-R will be a positive value, the variable is causal, and if it will be negative, it is considered as an effect.

Step 5: Calculate the threshold of relationships.

To determine the network relationship map (NRM), the threshold value must be calculated. In this way, partial relationships can be ignored and the valid relationships network can be mapped out.

Only relationships whose values in the T MATRIX are greater than the threshold values will be displayed on the NRM. To calculate the threshold relationship, it is sufficient to calculate the mean values of the T matrix.

After determining threshold severity, all the values of the T matrix, which is smaller than the threshold, are considered as zero, which means, the causal relationship is not considered.

Step 6: Generate paired comparisons Matrix.

In this step, the elements of each level are compared in pairs with other related elements at the higher level, and the matrix is formed up. In the end, the paired relationship of internal relations also must be formed up.

Step 7: Calculating Inconsistency Rates.

In this step, we calculate the inconsistency rate of the ANP matrix. If this rate is less than 0.1, it shows the compatibility of the matrix.

Step 8: Primary Super Matrix Formation.

By Using the weighted paired comparisons, we form the supermatrix.

Step 9: Create a Super Harmonic Matrix.

After creating the Super Matrix, we need to create a Super Harmonic Matrix.

Step 10: Create a Super sum Matrix.

The Super sum Matrix must be infinitely extended so that each row converges to a number. And that number will be the weight or benchmark.

Step 11: Forming up the Decision Matrix.

Step 12: Normalize the decision matrix.

To normalize the decision matrix, the following formula (formula 3) is used:

$$r_{ij} = a_{ij} \Big/ \sqrt{\sum_{k=1}^{m} a_{kj}^2} \tag{3}$$

Step 13: Create a non-scaled Weighted Matrix.

This matrix is resulted from multiplying an unbalanced matrix by the weights of the criteria (as calculated in step 10).

Step 14: Identify the ideal and non-ideal answer

$V_j^* = \max V_{ij}$ For the ideal positive criterion

$V_j^- = \min V_{ij}$ For a positive anti-ideal criterion

$V_j^* = \min V_{ij}$ For the ideal negative criterion

$V_j^- = \max V_{ij}$ For negative anti-ideal criteria

Step 15: Determine the distance criterion for the ideal alternative (Si*) and the minimum alternative (Si^-)

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^*\right)^2} \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2} \tag{5}$$

$$i = 1,2,\cdots,m$$

Step 16: Calculate the Similarity Index.

$$C_i = \frac{S_i^-}{S_i^- + S_i^*} \tag{6}$$

Step 17: Ranking the Options.

Any option that has a similarity index is superior [19].

3) Cam bearing frame concept design evaluation

In this section, the effectiveness of the proposed approach is evaluated by implementing the decision-making procedure steps for a typical IC engine component. For this, the cam bearing frame component has opted.

Cam bearing frame is a part of the engine that is a frame for holding camshafts and is an intermittent part between cylinder head and valve cover.

The main requirements for the design of this part are minimum manufacturing cost, ease of assembly, low noise vibrations and harshness (NVH), good sealing properties, and the possibility of camshafts lubrication.

In the following case study, 10 design criteria are evaluated to select the best design concept from 4 possible concepts. The four existing design concepts for this component are shown in Figure 1. In this study, three questionnaires have been designed to collect the data. They are needed to extract dependency between criteria, pairwise comparisons, and alternative scores respectively. The following of this section states the steps of the proposed approach.

3.1) Concept's introduction

possible components concepts alternatives of this research are listed as follows:

- Cam caps
- Bearing frame
- Bearing frame with valve cover
- Twin cam bearing frame

As shown in Figure 1, in the cam caps concept, each bearing has a separate bearing cap. This concept is very simple in the case of manufacturing and decreases the component weight compared with other concepts. The NVH level and the ease of assembly (assembly time) are the drawbacks of the concept.

The bearing frame concept is the second concept that is used commonly in IC engines. High weight and sealing problems are the drawbacks and very good NVH performance is the advantage of this concept. The third concept is an integrated bearing frame with a valve cover.

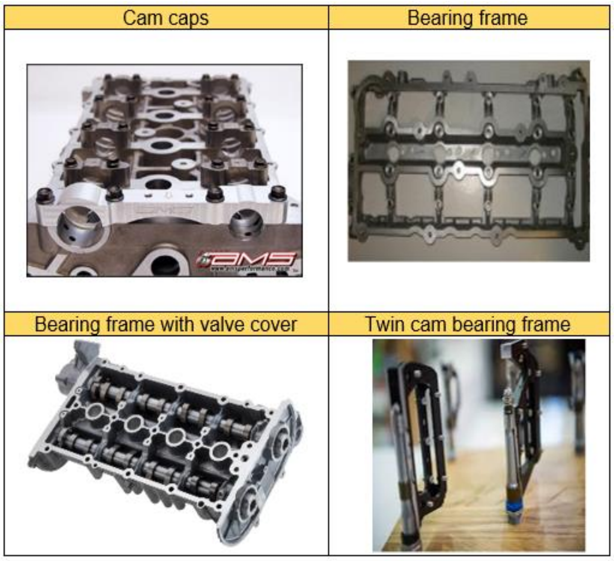

Figure 1: Evaluated concepts

This concept has not a sealing problem, but the manufacturing cost is high. The last-mentioned concept in Figure 1 is twin cam bearing frame that is used in some engines.

The sealing behavior of this concept is better than cam bearing frame and the assembly time is less than cam caps concept.

Selection of the appropriate concept for each engine depends on many parameters from noted concepts. In the below section, the important criteria in concept selection for this component are discussed.

3.2) Determination of the criteria

For concept evaluation of cam bearing frame concept, two types of criteria including qualitative and quantitative criteria are of importance. The evaluation criteria, need to be converted into quantitative and numerical values so that, multi-index decision-making calculations could be performed.

In this research, 10 criteria are considered for evaluation of the concepts:

1. Ease of manufacturing
2. Reparability
3. Ease of assembly
4. Packaging of fuel supply and ignition systems components
5. NVH
6. Weight
7. Price
8. Sealing quality
9. Lubrication of Camshafts
10. Accessibility to cylinder head bolt

As stated in Section 3, the first part of the proposed compilation method is to extract the matrix of relations between the criteria used by the DEMATEL technique. In the following section, steps are taken to implement the proposed merging approach for numerical examples.

3.3) Formation of direct-relation matrix

To form a direct-relation matrix in the DEMATEL method, a numerical range of 0 to 4 is used. Table 2 shows the concept of each of the numbers. In this regard, 0 refers to "NO impact", 1 refers to "Low impact", 2 refers to "Average impact", 3 refers to "High impact" and 4 refers to "Severe impact". Table 2 shows the matrix of direct relations experts' points of view.

Table 2: Direct-relation matrix

	A	B	C	D	E	F	G	H	I	J	SUM
A	-	0	0	0	0	2	4	0	0	0	6
B	0	-	4	2	0	0	1	0	0	3	10
C	0	2	-	0	0	0	0	0	1	4	7
D	0	3	4	-	0	0	0	0	3	0	10
E	1	0	0	0	-	1	1	0	0	0	3
F	1	1	1	1	1	-	3	3	1	4	16
G	3	0	0	1	0	0	-	0	0	0	4
H	0	1	1	1	0	0	0	-	0	1	4
I	0	2	0	0	1	0	0	3	-	0	6
J	0	3	3	3	0	0	0	0	0	-	9
SUM	5	12	13	8	2	3	9	6	0	12	16

3.4) Formation of normal direct relation matrix

In the next step of the DEMATEL method, to normalize the direct relationship matrix, each cell of the table is divided by the sum of its columns. Table 3 shows the matrix of normal direct relations.

Table 3: normal direct relations matrix

	A	B	C	D	E	F	G	H	I	J
A	0	0	0	0	0	0.125	0.25	0	0	0
B	0	0	0.25	0.125	0	0	0.0625	0	0	0.1875
C	0	0.125	0	0	0	0	0	0	0.0625	0.25
D	0	0.1875	0.25	0	0	0	0	0		0
E	0.0625	0	0	0	0	0.0625	0.0625	0	0	0
F	0.0625	0.0625	0.0625	0.0625	0.0625	0	0.1875	0.1875	0.0625	0.25
G	0.1875	0	0	0.0625	0	0	0	0	0	0
H	0	0.0625	0.0625	0.0625	0	0	0	0	0	0.0625
I	0	0.125	0	0	0.0625	0	0	0.1875	0	0
J	0	0.1875	0.1875	0.1875	0	0	0	0	0	0

3.5) Formation of total relations matrix

After performing the DEMATEL method, the final matrix of the total relations is according to Table 4. The total relationship matrix is the input of the ANP method to determine the weight and importance of the evaluation criteria. In this section, steps are taken to implement the ANP method.

Table 4: total relations matrix

	A	B	C	D	E	F	G	H	I	J
A	0.064041	0.035025	0.039194	0.042545	0.009524	0.1336	0.293845	0.028571	0.018777	0.051552
B	0.014788	0.158732	0.403084	0.210433	0.004181	0.00211	0.076775	0.012542	0.064781	0.319345
C	0.00341	0.235218	0.145536	0.093709	0.005625	0.000778	0.016051	0.016874	0.089215	0.331736
D	0.005041	0.307877	0.376669	0.071631	0.01413	0.073579	0.021669	0.04239	0.224567	0.154922
E	0.086034	0.018089	0.020116	0.019247	0.00519	0.018514	0.099259	0.015571	0.009465	0.027788
F	0.112683	0.228582	0.251772	0.190452	0.070851	0.025145	0.237857	0.212553	0.115103	0.373715
G	0.199823	0.02581	0.030891	0.074954	0.002669	0.000327	0.05645	0.008006	0.017556	0.019349
H	0.001725	0.126307	0.142893	0.102108	0.001776	0.004924	0.008498	0.005329	0.028096	0.122321
I	0.007549	0.169655	0.078435	0.046652	0.06368	0.004924	0.017394	0.19104	0.013957	0.06459
J	0.004357	0.319093	0.360992	0.257957	0.004488	0.000825	0.021468	0.013464	0.070981	0.151126

3.6) Formation of a paired comparison matrix

To obtain a matrix of paired comparison between criteria, the numerical scale of Table 5 is used. The paired comparison matrix of the evaluation criteria derived from the questionnaire is described in Table 6.

Table 5: Numerical range of Paired Comparison Matrix

The degree of importance	numerical
Similar preference	1
Identical to fairly preferred	2
Relatively better	3
Fairly strongly preferred	4
Strongly preferred	5
Strongly to be a very strong	6
Very strong preference	7
Too much to no avail	8
Extremely preferred	9

Table 6: Paired comparison matrix

	A	B	C	D	E	F	G	H	I	J
A	1	5	5	7	3	1	0.33333	0.25	3	0.14285
B	0.2	1	1	1	1	4	2	0.25	0.14285	1
C	0.2	1	1	1	0.5	4	0.3333	1	2	1
D	0.14287	1	1	1	2	3	2	1	2	1
E	0.333333	1	2	0.5	1	4	2	0.5	0.25	6
F	1	0.25	0.25	0.33333	0.25	1	0.125	0.16666	0.2	0.33333
G	3	0.5	3	0.5	0.5	8	1	3	5	0.25
H	4	4	1	1	2	6	0.333333	1	1	3
I	0.333333	7	0.5	0.5	4	5	0.2	1	1	0.2
J	7	1	1	1	0.16666	3	4	0.33333	5	1

3.7) Weight super-matrix formation

Weights super-matrices are presented to apply the effect of relationships and dependencies between criteria in paired comparisons. This matrix is obtained by multiplying the point to point of the paired comparison matrix and transforming the total normal matrix according to Table 7.

Table 7: Super-matrix weight

	A	B	C	D	E	F	G	H	I	J
A	0.040413	0.043184	0.000529	0.024381	0.001142	0.156013	0.01448	0.547304	0.03152	0.018054
B	0.00442	0.092703	0.271119	0.026092	0.083616	0.120906	0.11749	0.038357	0.275023	0.249086
C	0.004947	0.23541	0.306719	0.16881	0.378379	0.024118	0.129409	0.021328	0.336473	0.154116
D	0.003835	0.122897	0.219175	0.100449	0.270382	0.351125	0.073418	0.081626	0.063987	0.099234
E	0.002003	0.002442	0.022879	0.017139	0.002352	0.012502	0.036417	0.011006	0.006311	0.011912
F	0.084308	0.000308	0.000234	0.00106	0.000144	0.007362	0.002379	0.039006	0.000451	0.000206
G	0.556287	0.022419	0.00456	0.093628	0.067506	0.132221	0.244513	0.105239	0.009678	0.050992
H	0.072118	0.029299	0.034318	0.205667	0.014112	0.006251	0.163876	0.066035	0.037866	0.017868
I	0.00395	0.264834	0.012062	0.015026	0.074399	0.008224	0.073952	0.080279	0.100301	0.047237
J	0.227719	0.186504	0.128405	0.347677	0.107968	0.181278	0.144065	0.009821	0.13839	0.351295

3.8) Super-matrix Limit Formation

The Super Matrix Limit is obtained following Table 8, with the ability to bring the super-matrix to the point where divergence occurs, or in other words, all the super-matrix rows are identical.

Table 8: Super-matrix limit

	A	B	C	D	E	F	G	H	I	J
A	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355
B	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843
C	0.2246	0.2247	0.2246	0.2247	0.2246	0.2246	0.2246	0.2247	0.2246	0.2246
D	0.1431	0.1431	0.1431	0.1431	0.1431	0.1431	0.1431	0.1431	0.1431	0.1431
E	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
F	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042
G	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584
H	0.0441	0.0441	0.0441	0.0441	0.0441	0.0441	0.0441	0.0441	0.0441	0.0441
I	0.0827	0.0827	0.0827	0.0827	0.0827	0.0827	0.0827	0.0827	0.0827	0.0827
J	0.2134	0.2134	0.2134	0.2134	0.2134	0.2134	0.2134	0.2134	0.2134	0.2134

As it is shown in table 8, all elements of each row are equal. The final weight of the evaluation criteria derived from the DEMATEL-ANP combination method is shown in Table 9.

After determining the weight of the evaluation criteria, the TOPSIS technique is used to rank the options. The rest of this section shows the steps to implement the TOPSIS approach.

Table 9: Final weight of evaluation criteria

criteria	Weight
A	0.0355
B	0.184
C	0.2243
D	0.1429
E	0.0115
F	0.0042
G	0.0583
H	0.0441
I	0.0826
J	0.2131

3.9) Formation Decision Matrix

One of the strengths of the TOPSIS approach is to consider negative and positive criteria for decision making. In this regard, before the implementation of the TOPSIS approach, it is necessary to identify the positive and negative criteria. Table 10 represents the type of evaluation criteria.

Table 10: Types of Qualitative evaluation criteria

Criteria	Symbol	Criterion nature
volume Machining	A	Negative
Reparability	B	Positive
Ability to assemble	C	Positive
Compatibility of fuel system components	D	Positive
Sound, vibration, and abnormalities	E	Negative
Weight	F	Negative
Price	G	Negative
Sealing quality	H	Positive
Lubrication of camshafts	I	Positive
Access to the screw of the cylinder head	J	Positive

The matrix of concepts rating in each of the evaluation criteria from the experts' point of view is according to Table 11.

Table 11: Decision matrix

	A	B	C	D	E	F	G	H	I	J
1	6	2	2	3	3	3	3	3	6	2
2	6	2	2	2	6	9	6	9	6	4
3	3	2	2	1	9	9	9	9	3	2
4	6	2	4	6	3	6	6	6	6	4

3.10) Formation of a normal decision matrix

To normalize the decision matrix, this research uses the following formula (formula 7). The result is shown in table 12.

$$n_{ij} = r_{ij} \Big/ \sqrt{\sum r_{ij}^2} \qquad (7)$$

Table 12: Normal decision matrix

	A	B	C	D	E	F	G	H	I	J
1	0.555	0.5	0.378	0.424	0.258	0.209	0.236	0.209	0.555	0.316
2	0.555	0.5	0.378	0.283	0.516	0.626	0.471	0.626	0.555	0.632
3	0.277	0.5	0.378	0.141	0.775	0.626	0.707	0.626	0.277	0.316
4	0.555	0.5	0.756	0.849	0.258	0.417	0.471	0.417	0.555	0.632

3.11) The formation of a normal weighted matrix

At this stage, using multiplying the weighting of the evaluation criteria by the normal matrix, a normal weight matrix is obtained (table 13).

Table 13: Weighted Normal Matrix

	A	B	C	D	E	F	G	H	I	J
1	0.02	0.092	0.085	0.061	0.003	0.001	0.014	0.009	0.046	0.067
2	0.02	0.092	0.085	0.04	0.006	0.003	0.027	0.028	0.046	0.135
3	0.01	0.092	0.085	0.02	0.009	0.003	0.041	0.028	0.023	0.067
4	0.02	0.092	0.17	0.121	0.003	0.002	0.027	0.018	0.046	0.135
V_j^+	0.01	0.092	0.17	0.121	0.003	0.001	0.014	0.028	0.046	0.135
V_j^-	0.02	0.092	0.085	0.02	0.009	0.003	0.041	0.009	0.023	0.067

3.12) Options ranking

After completing the steps above, the final score of the concepts and ranking is obtained by table 14.

Table 14: Options Ranking

Option	Points	Rating
1	0.301538	3
2	0.395683	2
3	0.12033	4
4	0.886797	1

As can be seen in table 14, option 4 (double ladder format) is based on experts' opinions and the results of the combined approach of this research, with the highest score and subsequently the best ranked.

4) Conclusion

Choosing the right components for an automobile combustion engine system is one of the important issues in the proper operation of the combustion system. For component selection, it is necessary to take into account different and sometimes contradictory factors.

In this research, the problem of choosing the right component for an automobile combustion system was investigated using multi-criteria decision-making techniques. This research presented a combined approach including DEMATEL-ANP-TOPSIS for weighting and ranking of options.

In the beginning, the relationship between the criteria is determined using the DEMATEL method, and then the ANP method was determined by the weight of the criteria. Finally, the TOPSIS method was used to rank the options. To evaluate the options, this study considered 10 evaluation criteria. The results of the implementation of the proposed approach for the case study of Iran Khodro company indicated that option 4 (two-piece ladder frame) is the preferred option.

Moreover, the authors propose the use of fuzzy concepts in decision making and ranking of options for future studies.

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انتخاب مفهوم برای اجزای موتور با استفاده از روش ترکیبی دیمتل_آی ان پی_تاپسیس: مطالعه موردی برای قطعه قاب یاتاقان‌های بادامک

یوسف ربانی[۱*]، بهاره اسدی مقدم[۲]، احسان مردان[۳]، علیرضا حاجی‌علی‌محمدی[۴]

[۱] گروه مهندسی صنایع، دانشکده مهندسی، دانشگاه سمنان، سمنان، ایران، Rabbani@semnan.ac.ir
[۲] گروه مهندسی صنایع، دانشکده مهندسی، دانشگاه سمنان، سمنان، ایران، b.asadi1373@gmail.com
[۳] گروه مهندسی صنایع، دانشکده مهندسی، دانشگاه سمنان، سمنان، ایران، ehsan_mardan@semnan.ac.ir
[۴] گروه مهندسی مکانیک، دانشکده مهندسی مکانیک، دانشگاه سمنان، سمنان، ایران، ahajiali@semnan.ac.ir
** نویسندهٔ مسئول*

چکیده

انتخاب مفهوم مناسب برای اجزاء و سیستم‌های موتور یکی از موضوعات اساسی است که مستقیماً بر قیمت و خصوصیات عملکردی محصول تأثیر می‌گذارد. برای انتخاب مفهوم مناسب برای یک جزء موتور، لازم است عوامل متناقض مختلفی را در نظر گرفته شود. پارامترهایی مانند جنبه های عملکردی، دوام، هزینه تولید و مسائل مونتاژ معمولاً برای انتخاب بهترین مفاهیم مورد توجه هستند. در این تحقیق، ارزیابی مفهوم و انتخاب بهترین مفهوم برای یک جزء موتور با استفاده از تکنیک‌های تصمیم‌گیری چند معیاره بررسی شده است. مثال مورد استفاده در این مطالعه، بررسی مسئله انتخاب مفهوم قاب یاتاقان بادامک مناسب از بین چهار مفهوم موجود بر اساس ۱۰ شاخص اندازه‌گیری است. این تحقیق روش تلفیقی DEMATLE-ANP-TOPSIS برای مدل‌سازی و حل مسئله را ارائه نموده است. این تلفیق به این صورت است که در ابتدا با استفاده از روش DEMATEL، رابطه بین چند معیار تعیین می‌شود و پس از آن روش ANP وزن معیارها را تعیین می‌کند. سرانجام، از روش TOPSIS برای رتبه‌بندی گزینه‌ها استفاده می‌شود. این روش تلفیقی برای آن مثال بکار گرفته شد. نتایج استفاده از این روش تلفیقی برای مورد انتخاب شده نشان داد که قاب نردبان دو تکه (مفهوم ۴) گزینه ارجح است.

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